COSC 4P98 Lecture notes: **Algorithmic Composition**
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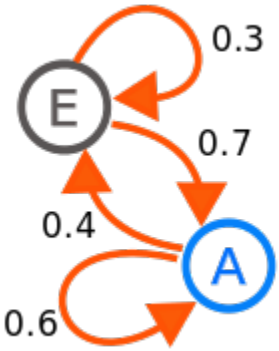
- Algorithmic composition: using an algorithm to make a composition
- There are many techniques. Some major ones are surveyed below.

1. Mathematical models

- Music has mathematical properties, be it at frequency level (harmonics), notes (scales, such as 12-note octaves; chords), note distributions (1/f), and higher-level compositional analyses.
- simple integer sequences can map to melodies; see "noise" lectures.
- One example: stochastic (probabilistic) music generators
    - Markov chain: a finite state-transition network, with different probabilities for state transitions.



["Markov chain", Wikipedia Commons]

- Can assign musical events (notes, sequences,...) to the nodes.
- To generate music, if you are at node E, then call a random number generator [0.0,1.0). If value less than or equal to 0.3, stay at E. Else go to A.
- This can be used to make generative music (aka Brian Eno)
- Complex probability tables with events can be used [Miranda 3.10]

2. Grammars

- Musicologists have studied music by formally modeling it with grammars. Music has a "linguistic" aspect similar to language, and may be closely related to human language structure and processing
- Note that a finite automaton is equivalent to a regular grammar.
- More complex grammars in the Chomsky hierarchy might be applicable to music representation as well. For example, Context-Free Grammars (CFG) have been applied to representing/modeling music.

- A music analysis formalism called Schenkerian analysis also takes a graph (grammar) viewpoint in modeling music.
- Once a grammar is created to denote music, it can be used generatively to produce music output.
    - Can also use stochastic grammar rules to do this probabilistically.
    - Does it sound good? That's a subjective issue.
- Examples: [Bell/Kippen p.370; Roads p.407]

3. Machine Learning

- Many artificial intelligence techniques have been used in music applications.
- Example 1: Machine learning
    - For example, using the Bell/Kippen data of "parse strings" of musical events, one can use ML to learn an automata or grammar that can recognize those strings.
    - Can also have "negative" strings of non-musical passages (ie. sound bad)
    - The resulting automata or grammar can then represent the style of the music, or even of the composer.
    - Can be used to recognize other examples of that composer's works.
    - Also can be used to generate music "in the style of" the original example music.

- Example 2: Evolutionary algorithms
    - Genetic algorithms have been extensively applied to learn musical melodies (among other applications)
    - A Genetic algorithm simulates Darwinian evolution and "survival of the fittest".
    - Pseudocode:
        - Fill a population with random strings. Each string is a melody. Evaluate each string based on its fitness (quality), and assign a quality score (eg. higher score is better).
        - Loop until solution found OR time limit reached {
            - Loop until the new population is filled up {
                - Pick 2 individuals based on fitness (higher fitness means more likely to be selected).
                - Apply a random "crossover" operation to the individuals. The new crossovered results are offspring.
                - Apply a random mutation to the offspring.
                - Evaluate the offspring quality.
                - Add offspring to a new population.

            } // popn loop

        } // generation loop

- Issue: what can be used as a fitness function? There are no known mathematical or computational theories as to what sounds "good". This is an interesting new area of research!
- Remedy: use a human listener as a fitness function. Human listens to passage, and rates on a scale of 1 to 10. ⟶ "Interactive genetic algorithm"
- note that there is a lot of research using GA's in music generation. Some styles of music (Jazz) have been pretty successful. (See research by Al Biles and his Genjam system). He uses it to automatically accompany his own trumpet playing.

- Example 3: Deep Learning and Jazz
  - https://deepjazz.io/

4. Knowledge-based systems

- This is another approach based on artificial intelligence technology.
- Expert system: A computer program that uses a knowledge base of human-level expertise.
- The KB can be used to analyze (parse) or rules for music generation. Can also be successful for accompanying, correcting, or embellishing music.
- KB can be created by discussions with a music expert, OR possibly created automatically using machine learning techniques (see above).
- eg. [Ebioglu p.313-4]

References:

- http://en.wikipedia.org/wiki/Algorithmic_composition
- *Understanding Music with AI*. Edited by B. Balaban, K. Ebcioglu, O. Laske. MIT Press, 1992.
- *Foundations of Computer Music*. Edited by C. Roads and J. Strawn. MIT Press, 1985.
- "Generation of musical sequences with genetic techniques", A.R. Burton and T. Vladimirova, *Computer Music Journal*, 23(4), Winter 1999, pp. 59-73.